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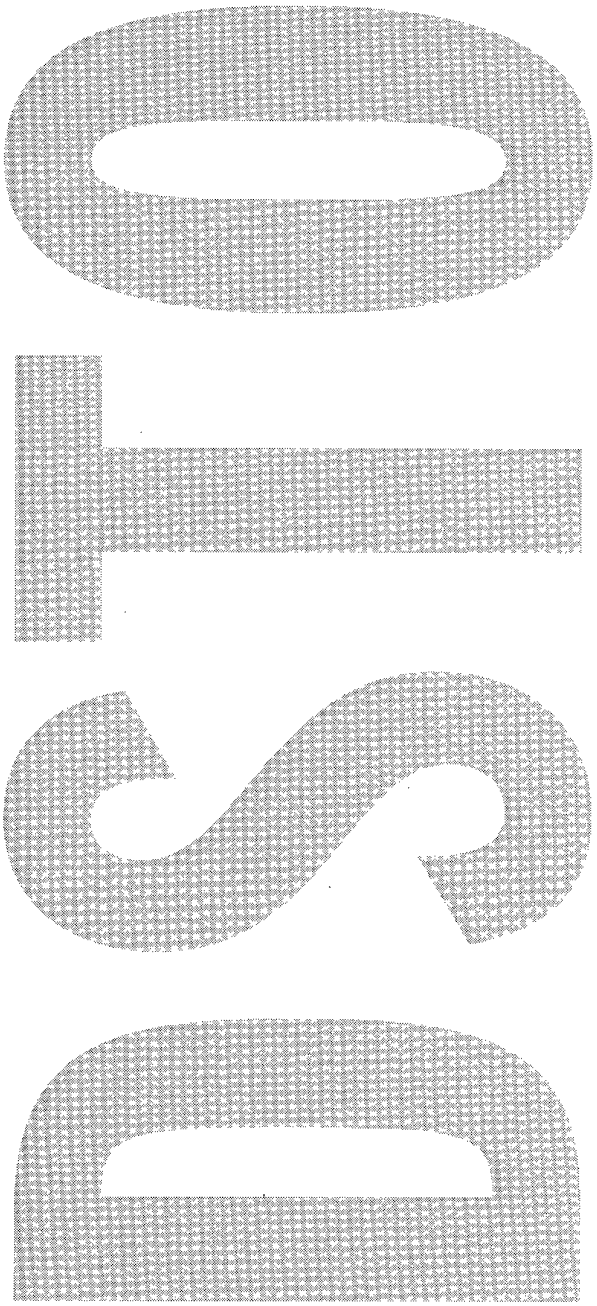

Systems Characterisation and Modelling Approaches for C3I

A.J. Yates, R. Vernik,
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DSTO-TR-0782

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ABSTRACT

The inherent complexity of C3I systems makes them difficult to understand. One way of overcoming this complexity is through the use of effective and efficient C3I systems descriptions. The C3I systems characterisation research outlined in this report is concerned with ways of defining C3I systems, and systems of systems, in terms of their elements and relationships. These elements, and relationships, form the basis for a C3I Systems Characterisation Model that reflects the different viewpoints, and information needs, of those involved with C3I systems. The research also makes use of visualisation, which is an important description technique, and recognises the importance of effective, and efficient, descriptions in helping Defence to improve its use, and management, of C3I systems information. This report provides an overview of the preliminary activities, and results, associated with the C3I systems characterisation research conducted as part of the "Characterisation of C3I for Takari" task (DAO 97/079). It provides supporting information and a motivation for new research directions into C3I systems characterisation.

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Executive Summary

The inherent complexity of C3I systems makes them difficult to understand. The factors that influence this complexity include: the number, and types, of components; the types of relationships that exist between the components; the distribution and the heterogeneous nature of the components; and the continually changing architectures which constrain the configuration of the components. These factors, and others, including ineffective descriptions and limited visualisations, make it difficult for planners, developers, users and researchers to fully understand the nature of C3I systems. These complexities are further compounded when systems are combined to form a fully integrated C3I capability (ie systems of systems).

C3I systems characterisation is concerned with the description of C3I systems. It is a way of defining C3I systems in terms of the elements, attributes, relationships and the environment in which C3I systems exist. Viewpoints, based on particular information needs, are used to help in the selection of the elements and the relationships, and to help in the creation of C3I systems, and systems of systems, descriptions. An enhanced understanding of C3I systems can be of direct benefit to capability planners, operations, training, acquisition, industry, and DSTO researchers.

The purpose of this report is to describe the activities and results associated with the C3I systems characterisation initial study that was carried out by researchers within the Software Systems Engineering Group (SSE). The report provides the background information necessary to support new research directions, and proposes a way ahead for future C3I Characterisation Work.

The study sought to gain an understanding of the type, extent, value and limitations of the information that is used by Defence to describe C3I systems. The results of the investigations showed that there is extensive information available that describes the different aspects of specific C3I systems. However, problems are often evident at different stages during the use and management of C3I systems information. C3I systems information is often distributed and difficult to locate. The very existence of information is often unknown. Access can be difficult. Information collection and assimilation is often ad-hoc and new information is not properly integrated with old information. There is an abundance of information that is not categorised or customised to meet users' needs. Also, there have been few attempts to integrate and model C3I systems information in order to produce systems of systems descriptions. Overall, these problems detract from the usefulness of the information.

Most of the information that explicitly describes particular aspects of C3I systems has been captured on paper, or in an electronic form. However, there is a great deal of C3I systems, and organisational, knowledge that people are aware of that has not been explicitly recorded. Also, there is a great deal of information that describes systems of systems that needs to be captured.

There are several issues that relate to the management and use of C3I systems information within Defence. The C3I systems information requirements of users need to be more fully understood. Those areas that are not effectively described by existing information need to be identified and improved methods for locating, accessing, categorising and customising C3I systems information need to be investigated.

Characterisation research is aimed at assisting Defence to better manage and use the information that describes C3I systems and, in particular, systems of systems. Modelling and visualisation are important aspects of the characterisation research. A C3I Systems Characterisation Model will help in understanding the links between the user information needs and the information that describes C3I systems. Such a model could help to bring together the essential, but different, viewpoints without the extraneous detail of full systems descriptions. Complementary visualisation research will support the development of efficient and effective ways of presenting C3I systems information so that it is most useful.

There is little information available to describe the performance and usage aspects associated with systems of systems. A better understanding of the different approaches that can be used to characterise the performance and usage of C3I systems could be important in helping Defence to manage these dynamic aspects of systems. A part of this research will investigate those aspects of C3I systems that are relevant to the characterisation of performance and usage.

C3I systems characterisation research can help Defence in its management and use of C3I systems information by providing insights into the information management problem and helping to develop approaches for resolving the issues, particularly those that relate to systems of systems. The research will help Defence to define the limitations of the current C3I systems information and to support the structuring and evolution of a managed C3I systems information space.

The application area of this phase of the characterisation research is towards producing effective descriptions of C3I systems. However, the method holds the promise of more general applicability and, with suitable tailoring, could be used to characterise other domains within the Defence enterprise.

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Alex Yates graduated in Electrical Engineering from the University of Adelaide in 1981. Upon graduation, he worked at the Australian Broadcasting Corporation as a television engineer on the design and development of remote control camera systems and television studio equipment. He joined the Defence Science and Technology Organisation in 1987 where he managed the design and development of fire control systems and associated test equipment for the Nulka programme. He has also provided systems engineering support to a number of major Defence projects. He is currently conducting research into systems characterisation and modelling approaches for C3I. His other research interests include systems analysis and lifecycle processes associated with the acquisition and development of C3I systems.

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Neelan Maheswaran has been with the Australian Defence Science Technology Organisation (DSTO) since 1990. Soon after graduating in Electrical Engineering at the University of Adelaide in 1985, he worked for the Submarine Warfare Systems Centre. During his time there he was a member of a team developing and maintaining software for the Oberon Class Submarine Fire Control System. Since joining DSTO, he has undertaken studies for Army on the computerisation of the Artillery Fire Control System and has also

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Abbreviations

ACOPS	Assistant Chief of Staff, Operations
ACSS	Air Command Support System
ADF	Australian Defence Force
ADO	Australian Defence Organisation
BCSS	Battlefield Command Support System
C3I	Command, Control, Communications and Intelligence
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CAMM2	Computer Aided Maintenance Management System – version 2
COMAST	Commander Australian Theatre
COTS	Commercial-Off-The-Shelf
CTD	Capability Technology Demonstrator
DAO	Defence Acquisition Organisation
DEFNET	Defence Communications Wide Area Network
DGISC	Director General of Information Strategic Concepts
DHQ	Defence Headquarters
DIO	Defence Intelligence Organisation
DJFHQ	Deployed Joint Force Headquarters
DoD	Department of Defence (US)
DSTO	Defence Science Technology Organisation
ESAD	Electronic Systems Acquisition Division
ESRL	Electronic Surveillance Research Laboratory
EXC3ITE	Experimental C3I Technology Environment
HQAC	Headquarters Air Command
HQAST	Headquarters Australian Theatre
HQNORCOM	Headquarters Northern Command
IO	Information Operations
ITD	Information Technology Division
JCSE	Joint Command Support Environment
JISE	Joint Intelligence Support Environment
JSSA	Joint Systems Support Agency
MILSATCOM	Mobile Satellite Communications
OISMAN	Operational Information Systems Manual
PRINCE	Projects in Controlled Environments
SCM	Systems Characterisation Model

SCMAC	Systems Characterisation and Modelling Approaches for C3I
SCMAE	Systems Characterisation, Modelling and Analysis Environment
SSE	Software Systems Engineering
TAFIM	Technical Architecture Framework for Information Management
VIDECS	Visualisation and Description of Component-based Systems

1. Introduction

1.1 Purpose

The purpose of this report is to describe the preliminary activities and results associated with the C3I systems characterisation work carried out by researchers within Software Systems Engineering Group (SSE). The report provides the background information necessary to support new research directions and propose a way ahead for future C3I systems characterisation work.

The C3I systems used by Defence are complex. The use of models and visualisation is needed to help to deal with the difficulties resulting from the complexity associated with C3I systems and to convey an adequate understanding of the components, and interrelationships. C3I systems characterisation can provide users and analysts with an important framework on which to base the modelling and visualisation of C3I systems.

This report is produced as part of the "Characterisation of C3I for Takari" initial study task (DAO 97/079). The task sponsor is the Director General of Information Strategic Concepts (DGISC).

1.2 Scope

This report identifies some of the important C3I systems issues that the Takari research programme [1] is intended to address and uses these issues to provide the motivation for the C3I systems characterisation work which is described in this report. The importance of this work to Defence and an account of the work done so far is presented along with some initial results. Some of the problems encountered in trying to use and manage C3I systems information are discussed and a description of future C3I systems characterisation research activities is given.

1.3 Report Overview

Sections 1 and 2 outline the purpose of this report, discuss the nature of C3I systems and define the main terms that are the used. Several of the factors that influence C3I system complexity are identified and the influence of complexity on understanding is discussed. Some of the problems that have been recognised when C3I systems are combined to provide enhanced command support capability are discussed and the main DSTO initiatives to help improve C3I are identified.

In Section 3, C3I systems characterisation is defined and the purpose of characterisation and the main benefits to Defence of C3I systems characterisation are given.

Section 4 outlines the activities associated with the initial study investigations and section 5 presents the results that were generated. The results are used to help with the identification of information needs and with the identification of some of the different types of C3I systems information, associated usage problems and management issues.

Section 6 links the characterisation research activities to Defence's need for better descriptions of C3I systems and improved management of C3I systems information. The types of research activities that are needed and some of the possible future characterisation environments are described.

Section 7 summarises the report and makes recommendations regarding future characterisation activities. The general applicability of the characterisation approach to other types of systems is also discussed.

2. The Nature of C3I Systems

The context for the characterisation research is provided through an understanding of the nature of C3I systems. In this section, the more important terms that are used throughout this report are defined. This is followed by a consideration of the impact of the inherent complexity associated with large C3I systems, and systems of systems, on the understanding of those systems. DSTO initiatives, in conjunction with the wider Defence Reform Program, are working towards improving this understanding in order to produce more effective and efficient C3I systems.

2.1 Definitions

2.1.1 System

There are many definitions for the word 'system'. The New Shorter Oxford Dictionary [2] provides a general definition of a system as "a group or set of related or associated material or immaterial things forming a unity or complex whole". Examples of systems can be found in many domains, eg engineering, science, economics, politics, biology etc. Consideration of this definition shows that there is a wide scope for the way that it can be applied.

Another definition, from the Electronic Industries Association [3], that is more closely aligned to the domain of interest in this report, defines a system as "An integrated composite of people, products and processes that provide a capability to satisfy a stated need or objective". The terms used here narrow the scope of application but this definition still retains the essence of the meaning given by the more general New Shorter Oxford Dictionary definition.

Kaposi [4] provides a more formal approach by defining a system **S** as a mathematical structure, an ordered pair that contains a set of elements and an associated set of relations.

$$\mathbf{S} = (\mathbf{E}, \mathbf{R})$$

Where $\mathbf{E} = \{\mathbf{e}_1, \mathbf{e}_2, \ldots \mathbf{e}_n\}$ is a set of elements,

$\mathbf{R}_E = \{\mathbf{r}_{E1}, \mathbf{r}_{E2}, \ldots \mathbf{r}_{Em}\}$ is a set of relations on the elements of **E**.

Without the relations $\mathbf{R}_E$ the elements of **S** remain disjoint. The relations "cement" the elements into a cohesive unity.

Systems can be described in terms of the attributes associated with the elements and the relationships. The relationships between the attributes can also be modelled. The Kaposi definition is useful for modelling and visualisation purposes and will be referred to later in the report.

2.1.2 Command Support System

ADF doctrine [5] defines a command support system as "An integrated information storage and retrieval system, together with the necessary personnel and utilities required to support

a commander at any level". The ADF Joint Command Support Environment (JCSE) is an example of a command support system.

There is ongoing discussion within Defence circles regarding what elements should be included when considering command support systems. A command support system must be capable of providing a variety of functions (eg planning, intelligence, logistics) to fully support commanders. It is these functions that ultimately determine the elements that make up the system.

Command support functions rely on the existence of underlying infrastructure elements consisting of people, hardware, software, processes and procedures. Changing business practices, new roles for commanders and the introduction of new technology have impacted on these functions and the way that they are implemented. As a result of these changes, there has been a change to the mix of elements in the underlying infrastructure. Many of the functions that were carried out previously by separate cells of people and equipment are now combined. This trend towards greater systems integration is likely to continue and functions, like logistics, maintenance and personnel are likely to be more directly visible to the commander.

2.1.3 C3I System

There is not a universally agreed definition for a C3I system, only a general understanding by workers in the C3I area, of the concept of a command support system as it is applied to those domains that encompass command, control, communications and intelligence. The notion of a 'C3I system' expands the application of the command support system definition to include these functions. The term 'C3I' is often used without other qualifiers to refer, in a general sense, to the C3I systems domain.

2.1.4 C4ISR Systems and C2*

C4ISR also expands the scope of application of the command support system definition to include, and explicitly refer to, computers (C), surveillance (S) and reconnaissance (R). The acronym C4ISR gives explicit recognition to those elements and moves closer to defining a more holistic view of all the elements that are important to a command support system domain. We have introduced the term 'C2*' to extend the holistic view concept even further by incorporating the symbol "*" to allow for the inclusion of any number of additional elements.

2.1.5 Systems of Systems

Just as systems can be decomposed into the elements from which they are constructed, they can also be combined in various physical and logical ways to form a system of systems. A system of systems is made up of elements that are systems. A system of systems may contain command support systems, communications systems, office systems, maintenance systems, logistics systems, meteorology systems. Figure 2-1 illustrates how a system of systems can be formed from particular instances of individual systems. The partitioning shown in Figure 2-1 is arbitrary. It is a convenient way of representing a system of systems.

HQNORCOM is an example of a system of systems. The command support functions at HQNORCOM are provided by a number of different types of interconnected computing and communication systems, eg MILSATCOM, BCSS, etc. People provide many of the

interconnection links that exist between the different systems, while effective processes are important in ensuring systems coordination and the efficient transfer of information between systems.

HQNORCOM is also an example of a higher level system that is part of a broader C3I system capability. It functions in a coordinated way with other higher level systems, eg HQAST and DJFHQ. This higher level grouping consists of systems of systems.

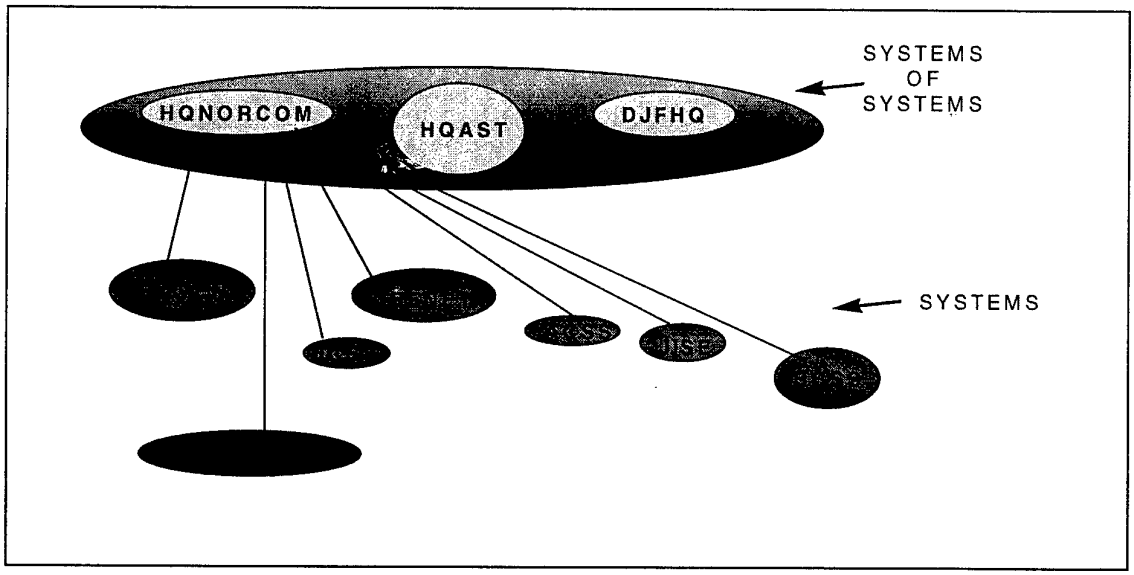

Figure 2-1 Systems of Systems

2.2 System Complexity

Many of the difficulties experienced in understanding C3I systems are due to the intrinsically complex nature of these types of systems. This complexity is influenced by many factors including, the number and heterogeneity of the components, the number of interrelationships, the distribution of components and change.

2.2.1 The Number of Components and Interrelationships.

C3I systems are made up of many different types of components and sub-components. These systems usually contain a multitude of computers, software, support equipment, communications circuits, people, policies, procedures and processes. The sheer number of components can be overwhelming. For each component to be a part of the system it must be related in some way to other components within the system. Because C3I systems have large numbers of components, there is the potential for many interrelationships to exist. These systems with large numbers of different types of components and interrelationships are difficult to analyse and understand.

2.2.2 The Distribution of Components.

C3I system components are usually widely distributed. The components can be located many miles apart, eg distributed networks linked by satellites and ground stations, or terrestrial communications paths, while the links that tie C3I systems together often do not

provide good visibility. For example, the C3I systems used by Defence, particularly during peacetime, have many dependencies on a largely unknown National Information Infrastructure (NII). The lack of visibility into the components that make up systems, due to their distribution, makes the understanding of those systems more difficult.

2.2.3 The Heterogeneity of Components.

The large number of components used in C3I systems are of many different types. Within a particular component type there can be many different versions. As all of the components have to fit together to form the system, it is important that all of the different types of components remain compatible. However, many components come from different suppliers and over the life of a system different versions of hardware and software are used throughout the system, eg software COTS releases.

Although the intent of standards is to help to maintain component uniformity, assist in the development of common operating environments and take economic advantage of the economies of scale, the large number of standards, the inconsistencies between them and their non-uniform application has resulted in the development of stovepipe systems. In recent times, there has been a move away from the use of Defence standards towards the use of commercial standards. Although this may, in the long term, improve efficiency, by reducing the number of standards in use, there is still some uncertainty within the Defence industry regarding which standards to adopt. This uncertainty continues to promote the use of different types of components.

2.2.4 Change.

Modern C3I systems are continually changing. New versions of products are continually being introduced. People are continually changing roles within the organisation. Procedures are continually under review. Technology advances in other than military areas are strongly influencing user demands. The need to maintain an overall Defence capability advantage is also driving the need for change.

C3I systems within the ADO are affected by these changes. For project JP2030 (JCSE) new capability is released every six months and there is no foreseeable end to this rollout. The Projects have become the deltas of the systems and it is difficult to define the boundary of these C3I systems because the systems are in a continual state of change.

2.2.5 Complexity and Information Management

These factors contribute to the inherent complexity that is generally associated with C3I systems. This complexity of C3I systems, along with the problems associated with the intangible nature of these systems, the inefficient management and use of the information that describes them and the lack of effective systems visualisations, needs to be addressed by Defence. Good management of the information that describes these systems is essential in helping planners, developers, users and researchers to understand the C3I systems. Without suitable information, the nature of these C3I systems will remain largely unknown.

2.3 Systems of Systems Issues

Systems can be combined to form systems of systems. However, combining systems multiplies the impact of the number of different components, the types of interrelationships and the distribution of components. Systems of systems can have the advantage of providing additional functionality, or emergent properties [6] that no individual C3I system can, of itself, provide eg, systems of systems have the potential to allow users at all levels within the Defence organisation to have efficient access to all Defence information sources. However, combining individual C3I systems also has the adverse effect of increasing the overall system complexity and introducing new problems that did not exist with individual C3I systems eg, problems relating to interoperability, integration and security.

Whereas individual C3I systems have Projects to manage their planning, acquisition and development, there has, in the past, been a limited systems management role within Defence to deal with the systems of systems interface and integration issues. Generally, individual Projects have had little control outside of their local C3I system domain and project personnel have had only a limited amount of knowledge about how their systems fit within the higher level systems of systems context. As a result, new problems have emerged when attempts have been made to interconnect and use C3I systems configured as systems of systems. Two major problems of special concern are those related to interoperability and security.

- **Interoperability.** There have been difficulties in connecting different C3I systems together to form systems of systems. For connectivity the physical and electrical interfaces must be the same at the lower levels, and for seamless communications the mission applications and support software must be compatible at the higher levels. For future expansion the underlying infrastructure needs to be adaptable and open. The use of common components, standards and common operating environments will lead to simpler and better integrated systems that have a common look and feel, provide more consistent information, and are easier to produce and maintain.

- **Security.** The large number of components and the distributed, and heterogeneous, nature of systems of systems have made them difficult to secure. Because of greater vulnerability, guarding against internal and external attacks requires greater vigilance. The integrity of internal security, which separates classified and unclassified material at the different levels within the systems, needs to be maintained as the systems are expanded. Immunity from external attack is more difficult because of the distributed nature of these systems and the greater reliance on the national information infrastructure.

2.4 Defence Initiatives for Improving C3I

This section discusses some recent initiatives by Defence, and in particular DSTO, that will help to provide a more uniform approach to the management of C3I systems. The DSTO initiatives provide a framework and a motivation for the characterisation research.

2.4.1 Defence Reform Program

Currently the Australian Defence Organisation (ADO) spends more than $2 billion dollars each year on the development and acquisition of systems [7]. However, much of this spending, particularly in the area of C3I, has been ad-hoc, resulting in systems that are not well integrated. The recent restructuring of Defence, and the introduction of the PRINCE project management methodology [8], is, in part, a direct result of the need for a more uniform acquisition approach to be adopted by Projects. This restructuring will allow Defence to work towards improving its development and acquisition processes in order to produce C3I systems consisting of software, databases, computers, and communications that are better integrated and more able to support the knowledge-based needs of the ADF.

2.4.2 DSTO ESRL Development Plan

The DSTO Electronic Surveillance Research Laboratory (ESRL) Development Plan [9], which supports the Defence restructuring strategy, recognises that knowledge obtained from superior information is an important ingredient for success in modern warfare. Accordingly, ESRL has initiated an integrated R&D program to support the knowledge superiority of the ADF.

2.4.3 Takari

A major initiative within the ESRL Development Plan is Takari. Takari is a research and development (R&D) program made up of a number of ongoing projects that are designed to support the ADF in its efforts to develop and enhance its integrated C3I/IO capability. Major General Jim Connolly, former Assistant Chief of Staff, Operations (ACOPS), and presently Commander Australian Theatre (COMAST) proposed the following vision for ADF C3I systems:

> "The Australian Defence Force is committed to an integrated C3I Information Management System, including policy, procedure and people, which provides all ADF commanders with relevant, reliable and timely information for the conduct of ADF Joint and Combined Operations for the defence of Australia and other activities directed by the Government."

This vision is referred to in the Takari Research and Development Plan [1]. The operational requirements for the C3I systems of systems used by Defence, shown in Figure 2-2, are derived from the vision statement.

- A single ADF C3I system with interoperable and integrated sub-systems covering all levels of command.
- A seamless and secure communications environment embracing all operational elements, with access to suitable databases for any mission.
- A common reference picture and data for senior commanders.
- An efficient and consistent flow of information between all levels of command.
- An identified set of inter-operability standards.
- A survivable system.
- An evolutionary program for the further development of an ADF C3I system.
- A management infrastructure for controlling and implementing policy, procedures and training.

Figure 2-2 ACOPS C3I Systems Operational Requirements

Although the list of operational requirements shown in Figure 2-2 is yet to be validated it does capture many of the major concerns that need to be addressed and hence provides a focus for DSTO research into C3I systems. In particular, it provides a motivation for the C3I systems characterisation work that is described in this report.

3. Systems Characterisation

This section describes what is meant by, and the purpose of, C3I systems characterisation. It also lists some of the benefits of characterisation that can accrue to the various areas of Defence.

3.1 C3I Systems Characterisation

3.1.1 What is C3I Systems Characterisation?

C3I systems characterisation is the process of defining the characteristics, or features, of C3I systems in terms of sets of system elements, attributes and relationships. The C3I systems characterisation discussed here is concerned with the description of C3I systems and the purpose of C3I systems characterisation is to support the production of more effective C3I systems descriptions. Because C3I systems are generally comprised of large numbers of interrelated elements, there are many possible systems descriptions that can exist. However, the number of descriptions actually developed is usually restricted to those that are of particular interest.

C3I systems are often described in terms of their physical, functional, performance, and other, attributes. In deciding which attributes to use when describing C3I systems, viewpoints, based on particular information needs, can help in the selection of the elements, and the interrelationships, used in the descriptions. Some systems can be viewed as a hierarchy made up of lower level systems, and their characterisation can contain many different viewpoints. At the higher context levels, a system may be viewed as an enterprise interacting with other organisations. At the lower levels, a characterisation may describe the physical nature of the hardware and software sub-components. The viewpoint adopted usually depends upon the information needs of the particular user.

An understanding of the physical nature of C3I systems is useful to systems analysts in helping them to understand and analyse internal and external information flows [10]. A physical description is often useful in helping to communicate ideas about the system and to form a basis for functional descriptions. The functional description, devoid of physical characteristics, can then be manipulated and new physical models created. For some descriptions, eg performance descriptions, the physical description is often essential in forming a basis for understanding.

3.1.2 Current Situation

A great deal of the information that describes particular aspects of individual C3I systems is created during system development. However, little work has been done in trying to combine this information to produce those characterisations that are suitable for describing systems of systems. The quality of C3I systems descriptions varies and, as there have been no studies to determine how well the descriptions meet the needs of the users, their overall effectiveness is unknown.

3.1.3 C3I Systems Information

The information content of messages is often the subject of C3I systems investigations. It is not this information content that is of primary interest in this report. The C3I systems information that is referred to here is that information which describes the elements, attributes and relationships associated with C3I systems, rather than the operational information that flows through the system.

3.2 Benefits for Defence from C3I Systems Characterisation

The major benefit that a characterisation of C3I systems will offer Defence is an increased understanding of C3I. Characterisation will help Defence to identify the essential (salient) parts of C3I systems and the associated links to C3I systems information. This will support information management within Defence. Thus characterisation is seen as an important mechanism for directly increasing C3I systems knowledge, and indirectly, the overall corporate knowledge of the Australian Defence enterprise. From this increased understanding Defence will be better able to plan the management and use of its C3I systems. C3I systems characterisation will directly benefit the following Defence areas:

- **Capability Planning.** There is a general need within Defence for reliable up to date information that describes C3I systems. The system descriptions provided through characterisation will provide planners with ready access to the information that they need to understand the capability limitations of the C3I systems that they are responsible for. It will help them to understand the systems of systems issues associated with improving the connectivity, interoperability and integration of C3I systems.

- **Operations.** The knowledge gained from the characterisation of C3I systems will help COMAST and other higher level commanders in support of missions and the day to day running of Defence operations. The information will help with the understanding of how C3I systems interact (eg information flows and usage patterns), and will allow the feasibility of different operational scenarios and system configurations to be more readily analysed. It will also help in assessing interoperability issues, particularly those relating to non-Australian defence agencies.

- **Training.** Concurrent with the increasing complexity of command support systems there is also an increasing diversity of the experience and backgrounds of personnel managing and using C3I systems. C3I systems characterisation will provide a wider range of more effective descriptions and so help in the training of people changing work roles.

- **Standardisation and Acquisition.** An effective way to help achieve C3I systems integration and interoperability is through the use of a common standards based technical infrastructure. C3I systems characterisation will help in providing an understanding of the elements that make up C3I systems. This understanding will help acquisition planners to standardise system developments, reduce the likelihood of stovepipe systems and help with the phased convergence to an open systems architecture. C3I systems characterisation information can be used to help standardise systems and processes within Defence. Acquisition planners that have ready access to reliable information regarding existing C3I systems will be in a better position to make informed development and acquisition decisions regarding the C3I systems that they are

responsible for. Significant financial, as well as operational, benefits will accrue from economies of scale and the ability to implement standardised C3I systems elements.

- **Industry.** Australian industry will also benefit from a characterisation of C3I systems. An improved understanding of C3I systems will improve industry's ability to plan and work cooperatively with the ADO.

- **Research.** The knowledge gained from an increased understanding of C3I systems will help to focus DSTO research and help to produce research outcomes that are more relevant to Defence. C3I systems characterisation will help research management to identify shortfalls in C3I systems capability and to direct research to those areas. The characterisation of C3I systems will directly support those areas of DSTO (eg, Information Architectures Group within ITD) directly involved in higher level command support analysis by providing a basis for the understanding of current and proposed C3I systems frameworks and infrastructures.

4. Initial Investigation

This section discusses the objectives and the activities associated with the initial investigations into C3I systems characterisation. The major users of C3I systems information within Defence are identified and their information needs, and links to information sources, are described. The collection, and assessment, of C3I systems information is also discussed.

4.1 Objective of the Investigation

The main objective of the initial investigation was to gain an understanding of the type, extent, value and limitations of the information that is used by Defence to describe C3I systems. The results of the investigation have been used to help formulate a future task that will investigate, using C3I systems characterisation approaches, those factors that are important in helping planners, acquirers, users and researchers to understand the nature of the C3I systems used by Defence.

4.2 Initial Investigation Activities

The initial investigations sought to identify the significant users of C3I systems information and to scope a representative sample of their information needs in order to gain an understanding of the information that is used by Defence to describe C3I systems. Following this, some typical examples of C3I systems information were identified, collected and assessed. The results of the investigation are described in Section 5 of this report.

4.2.1 Identification of users

There are many types of users of C3I systems information within Defence. This stage of the study sought to identify the significant users of C3I systems characterisation information. Researchers within DSTO helped to identify some of the likely user areas. Areas within Defence that were initially identified included the individual services, joint headquarters, the intelligence and acquisition organisations, and the DSTO. It was recognised that the different areas would have different interests and hence there would be some differences in their C3I systems information needs. The areas considered most likely to benefit from the research outcomes were DHQ, DIO, DAO and DSTO. These areas are seen as potential stakeholders in the C3I systems characterisation research.

To help in identifying the typical types of users of C3I systems information, discussions, and presentations that outlined the direction of the research, with a focus on the C3I systems information needs, were conducted with likely stakeholder representatives from various areas of Defence. Areas represented included the Information Strategic Concepts Branch in DHQ, the Command and Support Systems Branch in DAO, the projects including DEF 7013 (JISE), LAND 75 (BCSS), JP 2030 (JCSE), the Joint Systems Support Agency (JSSA), the Headquarters Air Command (HQAC). Researchers from the ITD and CD divisions of DSTO were also included. The feedback provided by the potential stakeholder representatives

during the presentations provided insights into the problems associated with the management and use of C3I systems information and helped to identify some of the possible future research directions, eg HQAC was identified as a potential case study.

4.2.2 Identification of information needs

Some understanding of user information needs is required in order to assess the limitations of the information that describes C3I systems. Selected users, drawn from the stakeholder areas, were included in a survey to determine their information needs. The survey consisted of a series of structured, and unstructured, interviews aimed at soliciting a representative set of C3I systems elements that required descriptions.

Table 4.1 shows a representative selection of C3I systems characteristics that were considered to be of interest to users working in the domain of C3I systems. The table is categorised into four areas: Function, Properties, Physical and Project. Function is concerned with information that describes what the systems, and their component parts, are intended to do. Properties address the quality issues of how well systems perform their functions. Physical is concerned with the details of the elements that make up the systems. Project is concerned with information products necessary to support development and acquisition activities.

A flier, produced to help to describe the objective of the characterisation study, helped to focus the survey interviews. The flier contained a representative list of C3I system characteristics (Appendix 1) that identified some of the more general physical, functional, performance, project and other related characteristics of typical C3I systems. The list of characteristics given in the flier was used to guide users of C3I systems information and help them to provide details of their particular C3I systems information requirements and to indicate how they preferred C3I systems information to be presented, or visualised.

Function	Physical
Information Flows	Architectures
Features	Configurations
Users/roles	Interfaces
	Formats
Properties	Locations
Geographic coverage	Environments
Speed	Software
Latency	Hardware
Usage	
Capacity	**Project**
Efficiency	Standards
Reliability	Plans
Availability	Status
Portability	Resources
Security	Contacts
Maintainability	Tools

Table 4-1: C3I Systems Characteristics

4.2.3 Identification of sources of C3I systems information

The identification of sources of C3I systems information followed on from the identification of users needs and during the interviews several users provided lists of sources and/or links to C3I systems information they were aware of. Because the users closely identified with the domain of interest, they were a valuable resource when it came to helping to identify where the relevant C3I systems information could be found and they were often able to provide the important links to help in locating the information they required.

Many DSTO researchers have built up a considerable amount of experience working in the C3I systems domain. Researchers, particularly within ITD and CD, were significant contributors in helping to identify, and provide links to and sources of, C3I systems information.

4.2.4 Information Collection and Assessment

Some representative examples of C3I systems information were collected and stored. These examples included Defence planning papers, project documents and DSTO research reports. Samples of C3I systems information generated during previous characterisation activities were also collected. Only information that had already been previously assimilated onto paper or into electronic databases was considered. As the intent of the investigation was to examine and report on the value of existing C3I systems information, no attempt was made to extract the C3I systems knowledge held by individuals, or to create new characterisation

information. Only a few samples of C3I systems information were taken during the investigation as the amount of data that was collected was not considered to be as important as the insights obtained. However, some important examples of C3I systems information that relates to systems of systems were included. The extent, and value, of the information collected was then assessed. The outcome of the assessment is discussed in the results section of this report. (Section 5).

5. Results of Initial Investigation

This section discusses the results of the initial investigation. Previous characterisation activities are evaluated and the main types of available C3I systems information are presented. Problems in using C3I systems information are identified and C3I systems information management issues are discussed.

5.1 Identification of information needs

Soliciting the C3I systems information needs was time consuming. For some users, two or more interviews were necessary to identify and establish useful contacts, convey the intent of the interviews and obtain meaningful data. However, the users were generally willing to cooperate and contribute, and some users were able to provide useful links to other sources of C3I systems information.

In some areas, difficulties were experienced in identifying information needs. Users who had given some consideration to their information needs prior to the survey were able to, relatively quickly, provide a list of their C3I systems information needs. Those users who had not previously considered what information they required in the context of C3I systems found identifying needs more difficult. Also, some users, because of the type of work they were involved in, had less need for C3I systems information than others.

In general, the information needs of users depended on their particular areas of interest. Also, the needs were not homogeneous within a particular area. Capability planners and researchers were generally interested in knowing about specific aspects of the physical, functional and performance characteristics of C3I systems. Those involved in acquisition, or development, were interested in the project information. Those involved with operations were interested in C3I system usage and availability information. However, there were common information needs identified between some of the different areas, eg system names and basic descriptions.

5.2 Types of C3I Systems Information

5.2.1 The Extent of the C3I Systems Information

The investigation found that there is a large, and diverse, amount of information that describes various aspects of specific C3I systems. A great deal of this information, particularly for the newer systems, comes from Acquisition Projects within the DAO. Other important sources of information reside within the systems at the various Command Centres, eg HQAST, HQAC.

Although most of these information sources are located within the Australian Defence Organisation (ADO) there is an increasing reliance on ready access to external information sources, within Australia and overseas. The Internet provides a great deal of information about Defence related topics, particularly those associated with the US Department of Defence. It contains vast amounts of information about C3I systems, projects, policies,

technologies, products and components. Specific examples of documents and electronic references that contain C3I Systems Information are given in Appendix 2.

Most of the C3I systems information is provided in a paper, or an electronic, form. The subject descriptions are generally limited to the system, its use and its interfaces. This type of information is useful in helping users to understand the details associated with particular systems. Table 5.1 summarises some of the common forms that C3I systems information can take.

Documents	Electronic Systems
Plans	Web sites
Specifications	Applications
Manuals	Tools
Studies	Databases
Reports	
Policies	**People**
Procedures	Knowledge
Work notes	Experience
Requirements	

Table 5-1: Common Forms of C3I Systems Information

People also, through their knowledge and experience with C3I systems, are valuable sources of C3I systems information and they can provide links to other important sources. However, knowledge is usually tacit. It remains with the people concerned and often is not recorded.

5.2.2 Previous C3I Systems Characterisation Activities

The results of the assessment indicated that there is a range of products that have been produced to describe particular aspects to C3I systems to meet the needs of specific users. However, only a limited amount of previous C3I systems characterisation work has tried to address characterisation issues across the totality of C3I systems. A key example of this work was the Operational Information Systems Manual (OISMAN).

The OISMAN initiative, started in 1995, produced a classified database that identified, and briefly described some general characteristics of Strategic, Operational and Tactical information, and communications, systems used by the ADO. It describes the features, and allows for some comparisons between the attributes, of different types of C3I systems. This work was not completed and no attempt has been made by any agency to keep the information collected up to date. The OISMAN makes no specific mention of the needs of users of the information. Although valuable, it was recognised that collecting information about C3I systems without a clear understanding of who was going to make use of the information, or what their information needs were, would be difficult to support because of the almost infinite extent of such an undertaking.

There have been other recent attempts within Defence to collect information that describes particular aspects of C3I systems. The most notable of these is the Compendium [11] that is released each year by the Electronic Systems Acquisition Division. The Compendium is intended to provide industry with an appreciation of the electronic systems capabilities being acquired by Australian Defence. It contains a brief description of the newer systems and some related project and industry information. It also provides useful links to sources within Projects that could be used to obtain further information about particular C3I systems.

5.2.3 Technical Architecture Framework for Information Management

An index was created to help keep track of the various documents collected. A few initial classification schemes for the information were considered and a scheme based on a taxonomy given in the Technical Architecture Framework for Information Management (TAFIM) [12] was adopted as an interim measure. TAFIM provides a common terminology and unifying database dictionary initiatives. It is mandated in the US DoD, although it has, as yet, not been adopted by all of the US DoD agencies. The main feature of the TAFIM model, of value to the characterisation task, is the proposed taxonomy used to help describe C3I systems. Although the taxonomy is not complete, it provides a substantial list of C3I system attributes that could be used for categorisation and classification purposes. Further investigations are needed to validate the suitability of the TAFIM taxonomy for use in future C3I systems characterisation research activities.

5.3 Problems with using C3I systems information

The information that describes C3I systems suffers from several problems. These problems are evident during the various stages of its use and management and can detract from its usefulness.

5.3.1 The Existence of the Information is often Unknown

Defence has produced, and continues to produce, large amounts of information that describes C3I systems. Finding out what information is available can be difficult. It is often not known if the information that describes the systems actually does exist, or if new information products need to be produced. Even if the information does exist, it is of no use if there is no knowledge of its existence. Searching for useful information can be very time consuming, and often without success because the desired information is not available.

5.3.2 Locating the Information is Difficult

Even if information is known to exist, locating the information can present problems. The location of the information may not be known. Searching does not always produce the desired results on the first try. Sometimes the required information is buried deep within a document, or within an application. Poor directions can lead users along the wrong path, which can waste time.

5.3.3 Information is Distributed

Usually, C3I Systems are widely distributed. Typically, the C3I systems components are located at various centres within Australia. However, some supporting components of

these systems may be located overseas. Usually, the information that describes these systems is also widely distributed. For the older legacy systems the information is often stored with the systems, or in stores, or libraries. Also, the people who plan, build, operate and maintain C3I systems are distributed sources of knowledge for these systems. For newer evolving systems (eg JCSE) much of the C3I systems information is stored with the Projects.

Figure 5-1 illustrates some aspects of the complex nature of C3I systems and the distributed nature of the information that describes these systems. The number of systems shown is representative. Communication systems and other types of support systems (eg Computer Aided Maintenance Management System - CAMM2) are included. Also shown in the illustration is how C3I systems can be combined to form systems of systems. DJFHQ is an example of a system of systems that is made up of instances of other systems including JCSE, ACSS, JISE and BCSS. In the diagram 'information clouds' are used to represent the information that describes each of the systems. The information that describes a system of systems, eg DJFHQ makes use of, and builds upon, the information that describes the individual systems.

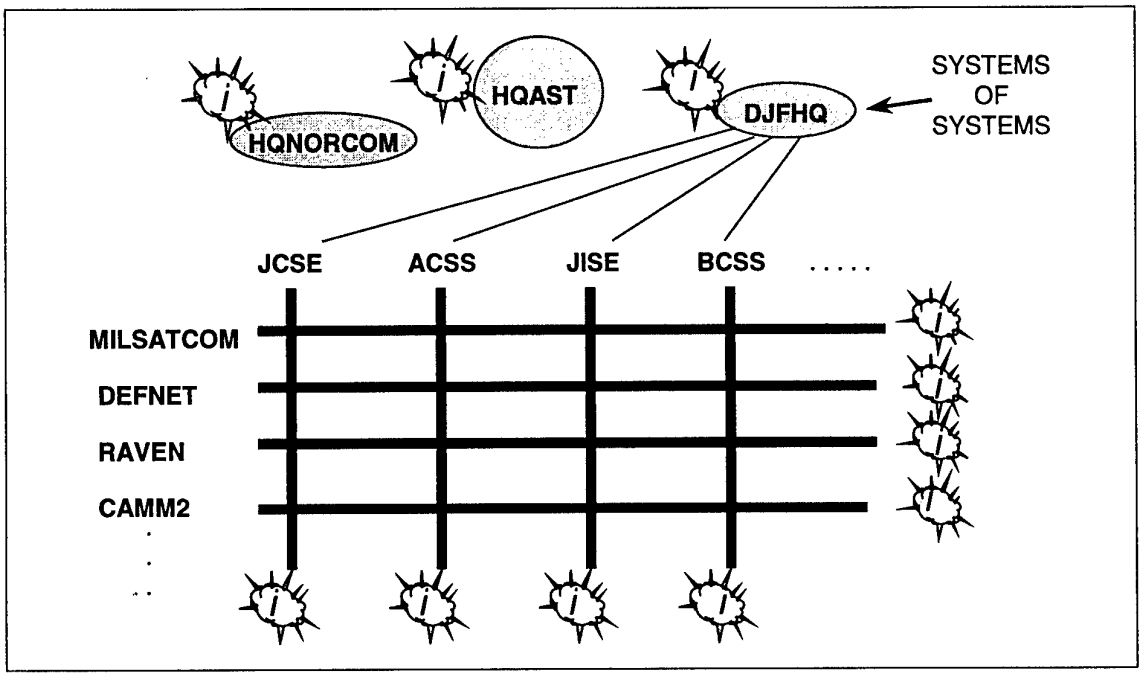

Figure 5-1 The Distribution of C3I Systems Information

5.3.4 Information is Outdated

The configuration of newer C3I systems is continually changing. The information that describes the systems should track these changes. While systems are being developed the Projects responsible for the systems generally maintain some form of configuration control over the products that they are responsible for. Once a system is in service the responsibility for configuration control usually changes from the Project, or Developer, to a maintenance organisation. In many cases the maintenance organisation is the user of the system. However, Projects and Developers often have different views of the systems to that

of maintainers and a lack of configuration control by the maintainers can result in C3I systems information that is dated and does not accurately reflect the build status of the actual systems.

5.3.5 Access to Information can be Slow

Even if the source of the information is known, obtaining timely access to the information can be slow. Even though electronic systems are much faster than paper based systems, frustration can result from waiting for on-line (eg Internet) services that are not readily available. These delays can directly affect the effectiveness of the information.

5.3.6 Information not Customised to Customer Needs

Often the information is available but not in a form that is easy to use, so extra work to carry out additional searching and sorting is needed. Accessing what you want from a complex source (eg, development file database) can be difficult. The information from various sources is often not assimilated and a great deal of time can be wasted searching through irrelevant sections of documents to find wanted material.

5.3.7 New Information is not Integrated with Old Information

New information is generated to satisfy new information needs. As new information is produced it is added to the existing C3I systems information space. However, within Defence there is no unified structured way of integrating new information with existing information. Without the appropriate links, finding information will become more difficult as the information space grows. If no consideration is given to how new information is to be integrated with existing information then there is the possibility that each new information product that is produced will be inconsistent in content and form with the information that already exists.

5.3.8 Information Collection and Assimilation is Ad-hoc

There is no systematic unifying method within the ADO for the collection and assimilation of C3I systems information, and there is no reference index that lists what information is available or where it might be located. There is a great reliance on people who have local or specialised knowledge of the whereabouts of information. As these people move within, or outside, the organisation to take up new roles and responsibilities this knowledge moves with them. Lost information can result in time consuming searches, or in the worst case, having to recreate the information from scratch.

5.3.9 Information is not categorised

Projects generate lots of information about C3I systems. Sometimes there is too much information available and users become overwhelmed. This can make efficient and effective searching difficult. Although there are standardised methods for categorising and classifying information these methods are not used in a consistent way across Defence. Titles, reference numbers, abstracts and key words are supplied with some types of information (eg, DSTO reports) but they are not available for all forms of C3I systems information. Document key words often have limited, or ambiguous, meanings. For these words, unintelligent search engines often produce results that are of little value.

5.3.10 Information often does not Address Systems of Systems Issues

A great deal of the information used to describe C3I systems is produced by Project and Contractor teams during the acquisition and development stages of projects. The scope of the development is usually restricted by financial considerations and Projects work within strict financial bounds in order to develop a new, or enhanced, military capability within budget. The policies of the past that have been used within Defence to integrate the different C3I systems development activities have had only limited success, generally resulting in C3I systems development across projects that has been ad-hoc. Many projects, concerned mainly with the detailed aspects of their specific systems, have given only limited consideration to the wider systems of systems issues.

There is a considerable amount of information available that describes individual systems. However, there is only a limited amount of information that describes systems of systems. The important systems of systems information which is missing includes that which describes the physical, functional and performance relationships that exist between the systems and between the systems and the environment in which those systems function.

5.3.11 The Uncontrolled Increase in Size of the Information Space

There is no systematic method within Defence for the management and controlled evolution of C3I systems information. As information is needed it is created and it becomes part of the information space, which is continually growing. Figure 5-2 illustrates how the information space increases in size as the information needs change and new information products are added. Without checks on the way that new information is generated and linked to existing information, the information space is able to grow out of control, making the management and use of the information more difficult. Unless you know where to look, there is the possibility that every time you want to find a particular piece of information every item in the information space would need to be searched. Computers can be used to speed up the process by searching for key-words, but unless information is structured in such a way that new information is properly integrated with existing information it will remain a difficult and time consuming exercise to find anything. Many users of Internet search engines are aware of the types of problems that can be experienced when trying to search through large amounts of unstructured information.

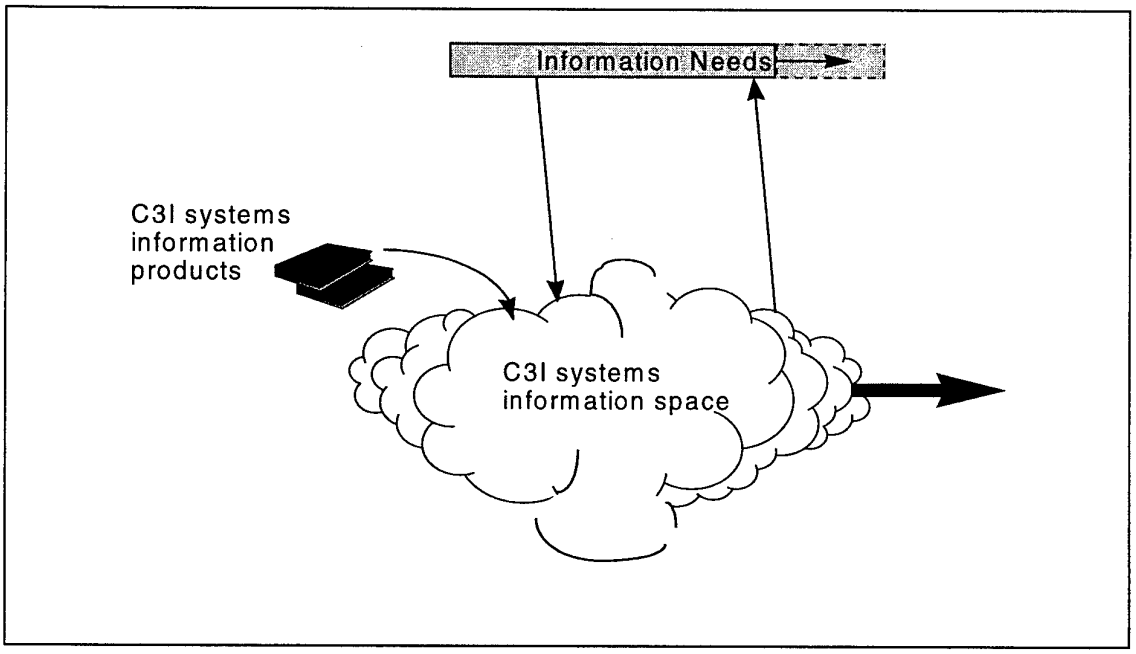

Figure 5-2 The Generation of C3I Systems Information

5.3.12 Information Management Problem

Good management of the information space that describes C3I systems is essential in helping to understand the nature of C3I systems. The problems identified during the initial investigation point to the need for a more effective and efficient way of managing the collecting, storing, retrieving, customising and use of C3I systems information.

5.4 Information Management Issues

The results of the initial investigation raised a number of important issues that relate to the management and use of the C3I systems information within Defence.

- **Information Needs.** Most of the users of C3I systems information come from the following areas within Defence: Capability Planning, Security, Operations, Maintenance, Projects, Industry, and Research. The information needs will, generally, depend upon the interests and viewpoints of the particular sets of users within each domain. The capture of the specific information needs of the users will help to define, and limit, the extent of the C3I systems information space that is to be managed.

- **Capture of areas not described by existing information.** Although there is a significant amount of information available that describes aspects of C3I systems there are still

major areas (eg performance issues relating to systems of systems) that are not well described. These areas, that can produce knowledge gaps, need to be identified.

- **Tacit Knowledge.** A great deal of the information that describes C3I systems resides with individuals as tacit knowledge that is not explicitly recorded. Mechanisms are needed to enable the capture and storage of this knowledge in order to share it with others within Defence.

- **Customisation of Information.** Information that is produced to meet specific user group requirements may not be in a form that is suitable for use by other users. If C3I systems information is provided in a form that makes it difficult to use, or manage, then some form of customisation of the information, in order to tailor it to the specific needs of the users, will be necessary.

- **Consistency of Information Sources.** Information describing C3I systems is available from different sources in different forms. To allow for the fusion of information it is important that the information remains consistent across the different sources.

- **Locating the C3I systems Information.** The information that describes C3I systems needs to be identified and located. Information needs can help in focusing the C3I systems information management activities. User groups are likely to be able to identify many of the possible sources of the information. However, much of the information that describes C3I systems, especially the newer systems, will come from Projects.

- **Automated Data Collection.** As C3I systems continually evolve, the information that describes them will continue to change. For information to be useful it will need to be updated regularly. Automated data collection needs to be considered. Ideally the information should be updated as systems change. Technology is now available that will allow software agents to be used to collect C3I systems information from distributed nodes. The technologies used to implement this automated type of information collection process can also assist in other aspects of the management of C3I systems information including access, interrogation, storage, maintenance and security of the information.

- **Information Accumulation and Maintenance.** It is important to have a defined process and a mechanism for systematically and progressively accumulating and maintaining the information that describes C3I systems. As new information is created it should be integrated into existing information so that the information space can evolve in a controlled manner. For this to occur there will need to be some consideration given to information categorisation, storage, maintenance and security.

- **Policies and Standards.** The controlled evolution of the information space will come about only through Defence management intervention. Policies and standards will be necessary to ensure that new information products are consistent with existing products and that the information management process is efficient and effective. Further characterisation research needs to be conducted to support the development of appropriate policies and standards.

6. Future Research

This section discusses the characterisation research needed to support C3I systems information management and lists some of the intended research activities. An environment necessary to support the research is also described.

6.1 Research to Support C3I Systems Information Management

6.1.1 Managed C3I Systems Information

For Defence to be able to understand its C3I systems it is important for Defence to be able to manage the information that describes them. Without a mechanism for management, the information space will grow uncontrolled and its use will be inefficient. The outputs of the research into characterisation, modelling and visualisation will help Defence to better manage its C3I systems information.

Figure 6-1 illustrates the relationship between the information needs and the information space in an environment controlled by a Defence C3I Systems Information Management Process. The inner rectangle within the C3I systems information space represents the managed part of the systems of systems information. It is a subset of the total information that describes C3I systems. The regular shapes within the managed information space represent new, controlled, information products. These products are common across the systems. The irregular shapes (clouds) within the information space represent information products associated with specific systems.

The management of the bulk of the information that describes specific systems can generally be left to the Projects. The parts of the irregular shapes that are included within the managed information space (inner rectangle) represent those elements and attributes of systems that can form meaningful relationships with other systems. The managed information space addresses the systems of systems issues.

With the introduction of new information products the size of the information space can grow. Through the Defence C3I systems information management process the size of the managed information space can also grow, but in a controlled way. The Defence C3I systems information management process functions as a systems integrator and ensures that the common interactions between systems are properly managed.

The SCMAC research will support Defence in its efforts to manage the C3I systems information management process. The characterisation will provide Defence with an improved understanding of the C3I systems domain, users' information needs, types of systems elements and their relationships, and the information sources that describe C3I systems characteristics. Research into systems visualisation and description will help in generating customised descriptions that support a range of user perspectives. Characterisation and visualisation research will directly support Defence in achieving control of the information that describes C3I systems.

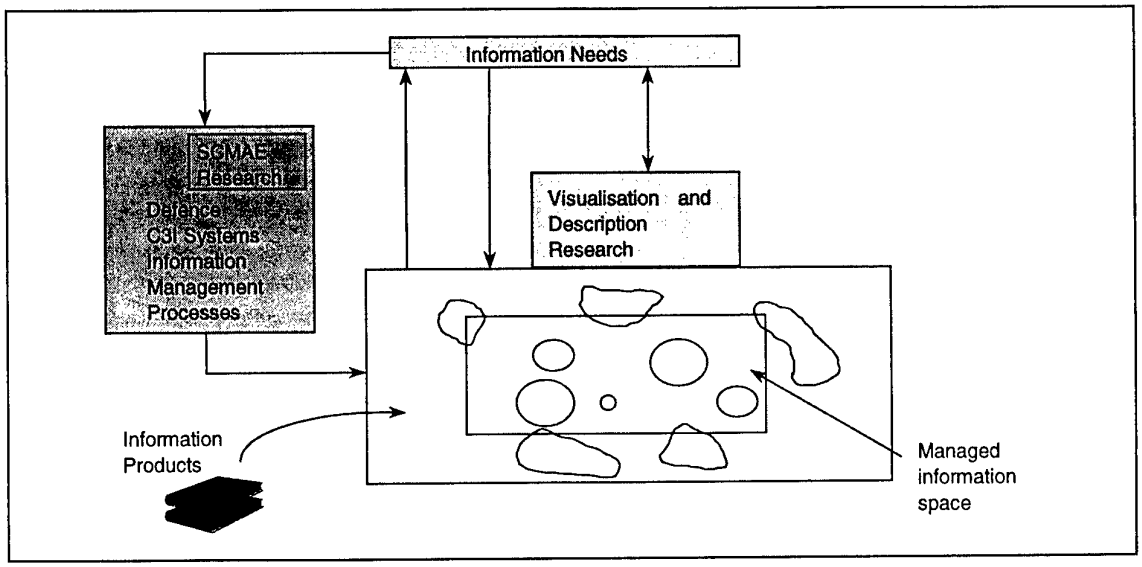

Figure 6-1 The Management of C3I Systems Information

6.1.2 Responsibility for Managing the C3I Systems Information Space

The responsibility for managing the information that describes C3I systems rests with Defence. Defence management have the responsibility for controlling the C3I systems information management process, setting policies, providing guidance and standards, and ensuring that the objectives set in delivering a well managed information space are met.

6.1.3 DSTO Software Systems Engineering (SSE) Research

DSTO SSE research is concerned with understanding and developing approaches which will support the management and use of the information that describes C3I systems, particularly from a systems of systems perspective. Research threads include:

- Modelling the C3I systems information needs and information space through the use of a consistent systems characterisation modelling approach.
- Modelling systems of systems dynamics (eg usage and performance).
- C3I systems information categorisation schemes.
- Automated information capture and storage.
- Computer based visualisation and description techniques.

Previous activities in the areas of software visualisation and description, and systems engineering, have contributed to the build up of experience and knowledge (within SSE Group) which is now able to be applied to the more general case of C3I systems description and visualisation.

6.1.4 Systems Characterisation and Modelling Approaches for C3I

The initial study investigation identified a Defence need for improved management of the information that describes C3I systems, particularly systems of systems. The proposed Systems Characterisation and Modelling Approaches for C3I (SCMAC) task is designed to provide a research basis for the systems of systems overviews which describe C3I systems and support C3I systems information management within Defence. Systems characterisation modelling and measurement approaches that can be used to describe C3I systems are being investigated. This research will facilitate the development of models and experimental tools for managing the collection, storage, retrieval, customisation and use of C3I systems characterisation information. It will also cover approaches for modelling and measurement of usage and performance. The overviews will assist planners, projects, users and researchers in understanding the scope, functions, usage, performance and interrelationships of C3I systems and provide a basis for the consideration and planning of future capability development.

6.2 Research Components

6.2.1 Modelling

Modelling is an important aspect of characterisation. Whereas C3I systems characterisation is concerned with defining the nature of C3I systems in terms of elements, attributes and relationships, modelling is concerned with ways of representing systems in order to aid understanding and communication. Modelling helps to simplify complexity by focussing on those things that are of importance. Without this simplification, and aid to understanding provided by modelling, characterisation would not be practically feasible.

6.2.2 Models and Viewpoints

A representative set of system elements, and relationships, can be used to model a system. The choice of system elements, and relationships, that are represented in the model will depend upon the system and the purpose for which the model is intended.

A viewpoint is a description that uses a subset of the systems elements, and relationships, used in the system model. The system model can support a number of different viewpoints. The physical, functional and performance descriptions of a system are possible examples of different viewpoints. Each set of users will determine the particular viewpoint that is most useful to them.

6.2.3 Systems Characterisation Model

Each viewpoint uses particular system elements and relationships to describe some aspect of the system. The elements and relationships from the different viewpoints can be combined to form the basis of an overall Systems Characterisation Model. The value of a Systems Characterisation Model is in its ability to bring together the essential, but different, viewpoints and provide a more complete description without the extraneous detail of a full system description [13].

6.2.4 Systems Characterisation, Modelling and Analysis Environment (SCMAE)

The C3I systems characterisation task will provide research support to the Defence information management process through the provision of a Systems Characterisation, Modelling and Analysis Environment (SCMAE). Figure 6-2 illustrates the Systems Characterisation Model with links to the information needs and to the information space. The SCMAE will provide an environment for addressing problems associated with the usage and management of C3I systems information, and will provide a mechanism for accessing, analysing C3I systems characterisation information and developing the Systems Characterisation Model.

The SCMAE will help in the systems modelling and with the definition of frameworks for classifying and developing semantic relationships about C3I systems element classes and attributes. It will also help to define the limitations of current C3I systems information and provide a better understanding of the C3I systems information space.

The SCMAE supports the evolution of the Systems Characterisation Model (SCM) which will be developed as part of the C3I systems characterisation research. The SCM can be described in terms of the formal systems modelling approach, referred to in Section 2.1.1, which uses system elements, {E} and relationships {R} [4]. This model will link the information needs of Defence users to the C3I systems information space. Users needs and information sources can be defined in terms of those aspects of the C3I system that need to be described (in terms of the SCM). Analysis of the information needs and the information space will help to determine the appropriate links to be included in the model. By defining information needs and information space in terms of an underlying SCM we can control and limit the scope of the problem addressed by the C3I systems information management process.

Within the SCMAE environment users will be able to express their needs for system descriptions in terms of the sets of system elements, attributes and relationships that are of interest. The environment will allow the capture of user knowledge of systems characteristics and known sources of system characterisation information. It will also allow the capture of specific information about the information sources in the underlying information space.

By analysing information sources in terms of the system characteristics that they describe, and the formal systems characterisation modelling approach [4], knowledge of the system being characterised will be enriched. Through an iterative application of this approach, systems characterisation knowledge from a range of underlying information sources, and user perspectives, will be captured.

The resulting Systems Characterisation Model will provide a consistent source of information that will:

- Support an understanding of the key classes of C3I systems elements and related system characteristics.
- Identify those aspects that are not described by known information sources.
- Identify those sources of information that describe specific systems characteristics.

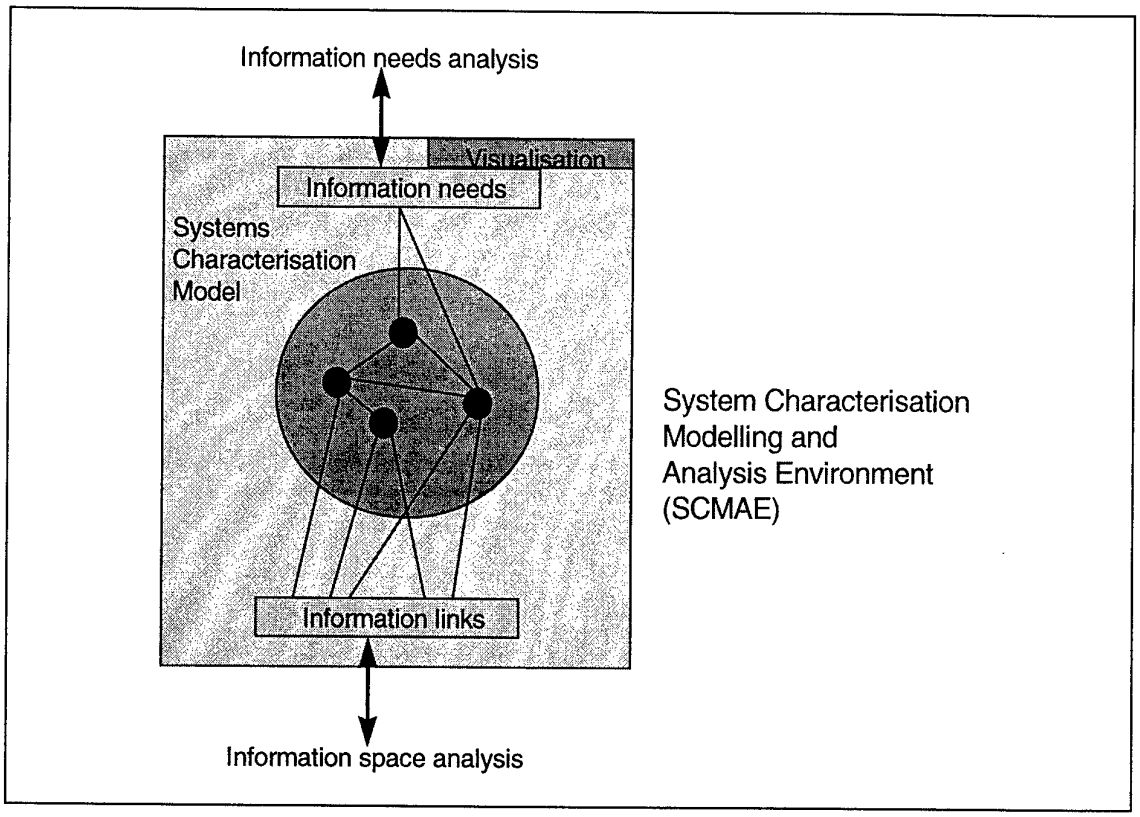

Figure 6-2 Systems Characterisation, Modelling and Analysis Environment

6.2.5 Visualisation

The way that the information that describes C3I system characteristics is presented is critical to its understanding. Visualisation is concerned with developing efficient and effective ways of presenting C3I systems information so that it is most useful. Use of computer-based visualisation is a flexible and customisable way of representing the different features of C3I systems. The method used to visualise information will depend upon the needs of the users of the information and the visualisation technologies that are available. The form that the information takes will influence its effectiveness.

6.2.6 Visualisation Research

It is important to be able to access, integrate, customise and adapt information to provide representations that will meet user information needs [13]. Visualisation and description research will provide approaches for accessing, integrating, and filtering the information that describes the C3I systems information. Defence needs flexibility in its ability to filter and display information for analysis. Visualisation research, based on early work associated with software systems, is in progress within SSE group. Currently, the Visualisation and Description of Component Based Systems (VIDECS - DAO 97/127) task is researching approaches for more effectively documenting and gaining visibility of large C3I projects and

products through the use of computer-based visualisation approaches. Topographic views, clustered graphs and overlays are being used to help with the understanding of the elements and interrelationships that exist between C3I systems.

6.2.7 Visualisation Tools

Visualisation can help users to model and analyse the interrelationships that exist between C3I systems elements. Appropriately tailored visualisation tools can simplify the interrogation of large databases. The SCMAC research will provide the VIDECS researchers with a case study in which visualisation components will be assembled to provide a visualisation environment suitable for visualising the C3I domain. The research will identify suitable adaptations for visualisation tools, and their associated components, to meet the different visualisation needs of the various users of C3I systems information.

The SCMAE environment (Figure 6-2) includes a visualisation window that can help to provide access to the C3I systems characterisation information. This window provides a means of viewing the user needs and the characteristics of the information space used in the Systems Characterisation Model.

6.2.8 C3I Systems Dynamics

There is a considerable amount of information available that describes C3I systems. Most of this information is produced by Projects during the development of these systems. However, a great deal of this information is specific to particular systems and describes mainly the functional and physical properties of the systems. There is less information available to describe the dynamic (eg, performance issues like throughput, latency and system usage) aspects of C3I systems. This lack of dynamics information is particularly evident in those aspects that relate to systems of systems issues.

The C3I systems dynamics research is addressing the need for information that describes the dynamics aspects of distributed C3I systems. An important part of this research will be to model, measure and analyse the dynamic aspects of C3I systems and to establish measures that can be used in future characterisation comparisons. C3I systems dynamics descriptions, derived from the research, will contribute directly to those elements of the managed information space that describes systems of systems.

6.2.9 Characterisation Modelling Links to Visualisation and Dynamics

The research links that relate the visualisation and dynamics to the characterisation modelling and analysis are shown in Figure 6-3. Outputs from the visualisation research will support the characterisation by helping to describe C3I systems from different user viewpoints, and outputs from the characterisation will provide realistic scenarios from the C3I systems domain that will help to refine the visualisation models and the selection of visualisation tool components.

The dynamics activities will provide the characterisation research with important performance descriptions and measures regarding C3I systems and systems of systems. Outputs from the characterisation will help to focus the dynamics activities by providing detailed user needs for dynamics descriptions.

The process is seen as ongoing with the outputs from the characterisation, visualisation and dynamics research directly supporting Defence in its endeavours to manage the information that describes C3I systems.

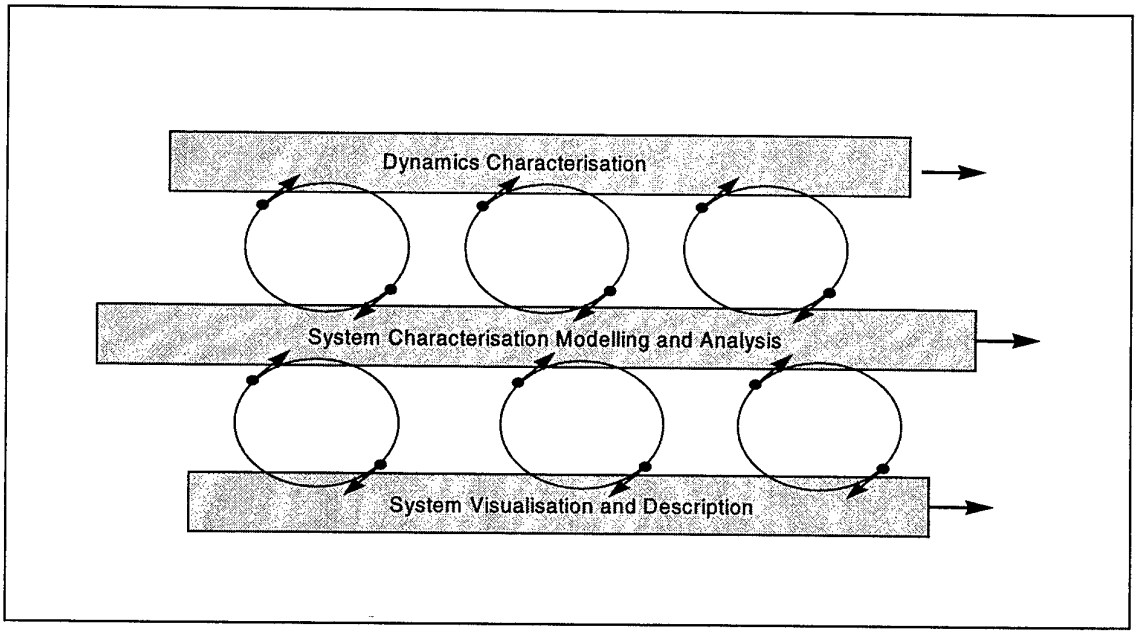

Figure 6-3 Research Links between Characterisation, Visualisation and Dynamics

6.3 Research Environments

6.3.1 Characterisation Laboratory

The characterisation laboratory will assist the modelling and tool development by providing a suitable research infrastructure for storing and maintaining C3I systems information in a secure environment. Experience gained from the use of the laboratory will assist in providing insights into some of the wider Defence problems and issues related to C3I systems information management.

6.3.2 Characterisation Tools

The SCMAC task will investigate the use of appropriate information management support tools and components. These tools will support the research by assisting the capture of user needs, C3I systems information, modelling and visualisation. The knowledge gained from the development and use of these research tools has the potential to support other areas of Defence involved in the future management and use of C3I systems information.

6.3.3 C3I Characterisation Case Studies

To validate the characterisation approach taken, the research activities will include an ongoing series of case studies in which different viewpoints will be investigated and the resulting accumulated knowledge will be used to develop a systems characterisation model for the information that describes C3I systems. An initial characterisation environment is

being established, and appropriate support tools developed. As future investigations progress, the characterisation laboratory, and the tools, will be modified to suit the different user viewpoints. The case studies will be based on the needs of particular user groups. The initial case study will consider the information needs of planners, users and researchers in an area such as Information Operations. Subsequent case studies will take their direction from the results of the initial case study.

6.3.4 Support for EXC3ITE

A self-contained laboratory, suitable for investigating the dynamics characterisation aspects of C3I systems, is being developed within SSE. This dynamics laboratory will be capable of acting as a node within the EXC3ITE infrastructure. It will provide an opportunity for the outputs of the dynamics research to be progressively integrated with other DSTO research initiatives that are supported by the EXC3ITE infrastructure. Dynamics aspects include usage and performance modelling of distributed software applications and middleware, system network monitoring, network visualisation, and network management. The results of the research investigations done within the EXC3ITE environment will be transitioned to other operational C3I systems environments through suitable agencies (eg, Joint Systems Support Agency) at the appropriate development stages of these operational systems. Network management, usage and performance tools are being configured for use within the dynamics laboratory, and within EXC3ITE. Figure 6-4 shows the flow of research products from the dynamics laboratory within SSE to EXC3ITE and to operational C3I systems. At each stage the analysis of the results is fed back to earlier stages to help direct future dynamics research.

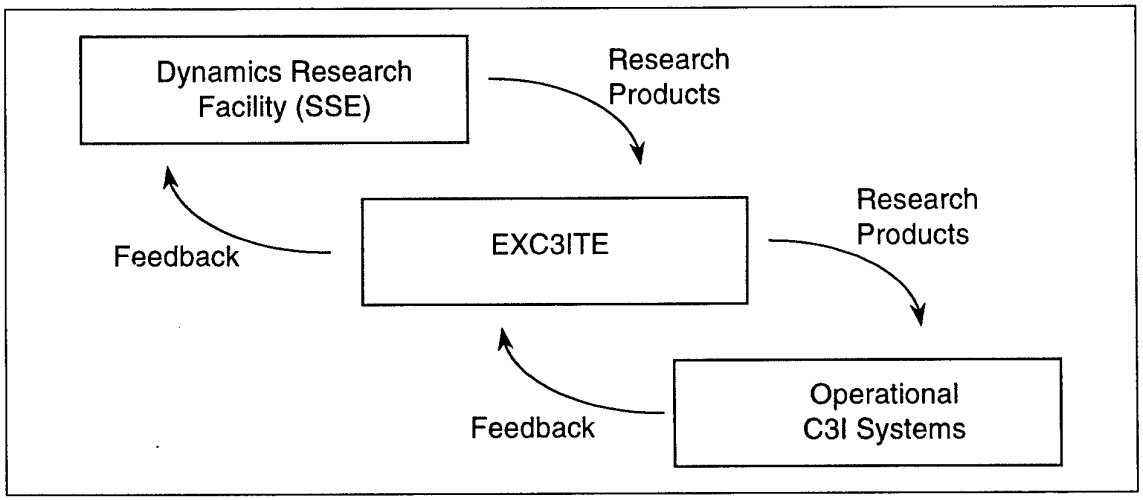

Figure 6-4 Flow of Dynamics Research Products to Defence

7. Conclusions and Recommendations

The inherent complexity of C3I systems makes them difficult to understand. A large part of the complexity is due to the large number of distributed heterogeneous components that the systems are composed of and the large number, and different types, of interrelationships that can exist between the components. The problem of understanding is compounded when C3I systems are combined to form systems of systems.

C3I systems characterisation is a way of defining C3I systems in terms of sets of system elements, attributes and relationships. Because systems are composed of many interrelated elements there are many possible characterisations that can result. The viewpoint chosen depends upon the particular information needs of individuals.

The descriptions provided through a characterisation of C3I systems will help capability planners, acquirers, developers, users and researchers to understand the nature of C3I systems. This understanding can be used to assist other Defence agencies in understanding higher level organisational activities.

The initial investigations revealed that there is a great deal of information available in the form of reports, specifications, manuals, policies and procedures, that describe particular aspects of C3I systems, but the information, its form, and its management and use, have limitations which detract from its usefulness. Systems of systems issues are poorly addressed. C3I systems information is often distributed and difficult to locate. Often the very existence of information is unknown. Access can be difficult. Information collection and assimilation is ad-hoc and new information is not integrated with old information. Also, there is a growing information space with an abundance of information that is not categorised or customised to meet users needs.

Defence needs a more efficient and effective way of generating, managing and using C3I systems information. The information requirements of users, and areas not effectively described by existing information, need to be identified, and improved methods for locating, identifying, categorising and customising C3I systems information need to be found.

Characterisation research can help Defence, which is ultimately responsible for managing C3I systems information, by providing insights into the problem and helping to develop approaches for resolving the information management issues, particularly those relating to systems of systems.

Modelling and visualisation are two important aspects of the research. The development of a systems characterisation model will bring together the essential, and different, viewpoints without the extraneous detail of a full system description. The systems characterisation model will link the user information needs to the information space that describes the C3I systems. Visualisation research will assist in providing efficient and effective ways of presenting C3I systems information so that it is most useful.

The C3I systems characterisation research will help Defence to define the limitations of the current C3I systems information and to support the structuring and evolution of a well managed C3I systems information space. The characterisation of C3I systems information would provide an evolving reference for details on C3I systems. The characterisation research will help Defence to understand how the information that describes C3I systems can be managed and used more efficiently and effectively.

Although the target application area for the characterisation in this instance is C3I systems, the approach has much wider application. Information is used by Defence to describe all sorts of things, conceptual as well as tangible. With appropriate tailoring, many of the ideas and processes applicable to the characterisation approach to be used with the C3I systems described in this report could be usefully applied to other domains within the Defence organisation.

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Appendices

Appendix 1: Example C3I systems characteristics in flier.

System name	General description
Physical location	Security classification
Number in service	Expected life
Power requirements	Service user
Availability	Number of operators
System architecture	Operational environment
Programming language	System capacity
Interfaces	Current system status
Communications protocols	Cost
Signal characteristics	Associated project
Displays	Developer
Hardware technologies used	Maintainer
Operating system	Contacts
Portability	Standards used
COTS usage	Development tools
Memory capacity	User interface
Code size	Sensor information
Multimedia format	

Appendix 2: Some examples of C3I systems information

Operational Information Systems Manual
Operational Information Systems Master Plan
DSTO report: C2 Analysis during K-95
DSTO report: C2 Support Study
DSTO report: Wide Area Information Surveillance Study
C4ISR Architecture Framework
Technical Architectures Framework for Information Management (TAFIM)
Defence National Telephone Environment Study
Compendium
HQAST Information Flow Study
http:web.cccs.mil.au/acss
Defence on Disk
Defence Managers Toolbox
Lotus Notes Databases - JP2030 Tasking Database
Lotus Notes Databases - JCSE Configuration
Defgrams
Australian Defence Monthly
C3I Interoperability Study

Appendix 3: A selection of user needs

System throughput	Communication systems interdependence
Geographical location of systems	System utilisation
Communication bandwidths	Power supply capacity
Software costs	Development standards used
System architectures	Software architecture
System Developers	Number of system nodes
Location of servers	Location of encryption units
Satellite geographic coverage	Antenna dish sizes
Interoperability of systems	Location of systems
Software sizes	Software types
Software versions	Software distribution
Types and locations of disk drives	Disk drive storage capacities
Transmitter frequencies	Maintenance organisations
Deployability of systems	Availability of systems

Systems Characterisation and Modelling Approaches for C3I

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19. ABSTRACT
The inherent complexity of C3I systems makes them difficult to understand. One way of overcoming this complexity is through the use of effective and efficient C3I systems descriptions. The C3I systems characterisation research outlined in this report is concerned with ways of defining C3I systems, and systems of systems, in terms of their elements and relationships. These elements, and relationships, form the basis for a C3I Systems Characterisation Model that reflects the different viewpoints, and information needs, of those involved with C3I systems. The research also makes use of visualisation, which is an important description technique, and recognises the importance of effective, and efficient, descriptions in helping Defence to improve its use, and management, of C3I systems information. This report provides an overview of the preliminary activities associated with the C3I systems characterisation research conducted as part of the "Characterisation of C3I for Takari" task (DAO 97/079). It provides supporting information and a motivation for new research directions into C3I systems characterisation.